

VSS121

APEEM Components Analysis and Evaluation



Principal Investigator:
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**2014 U.S. DOE Hydrogen Program and
Vehicle Technologies Program Annual
Merit Review and Peer Evaluation
Meeting**

June 18, 2014

OVERVIEW

Timeline

- Project start date: Oct. 2012
- Project end date: Sept 2014

Barriers*

- “Validate, in a systems context, performance targets for deliverables from the Power Electronics and Energy Storage Technology R&D activities”

**from 2011-2015 VTP MYPP*

Budget (DOE share)

- FY13 funding:
 - VSST: \$300k
 - APEEM: \$200k
- FY14 VSST funding: \$200k

Partners

- DOE VTO Advanced Power Electronics and Electric Motors (APEEM)
- Oak Ridge National Laboratory
 - Power Electronics & Electric Machinery Group
- USDRIVE EETT/VSATT

RELEVANCE

- **Directly supports:**

- VSST cross-cutting activities :Modeling and simulation; component & systems evaluations; vehicle systems optimization.
- APEEM testing activities

- **Indirectly supports VSST laboratory and field vehicle evaluations.**

- **Addresses the following VSST Barriers:**

- **Risk aversion:** Generates experimental measurements to support model-based simulation and analysis.
- **Cost:** Utilizes ORNL VSI lab + data and models from other OVT projects.
- **Constant advances in technology:** Emphasizes latest advanced high efficiency combustion and power electronics and electric machinery.

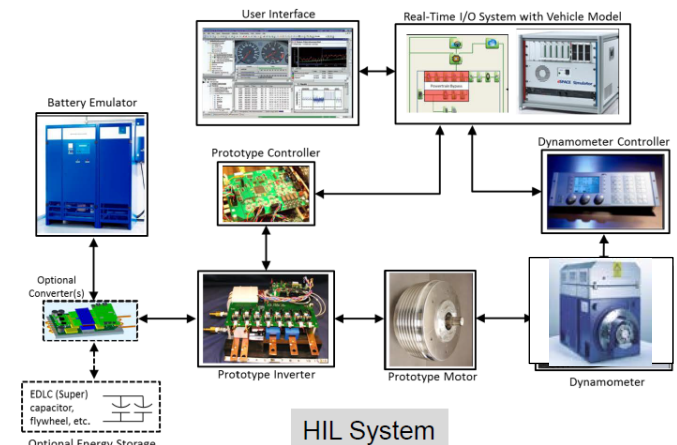
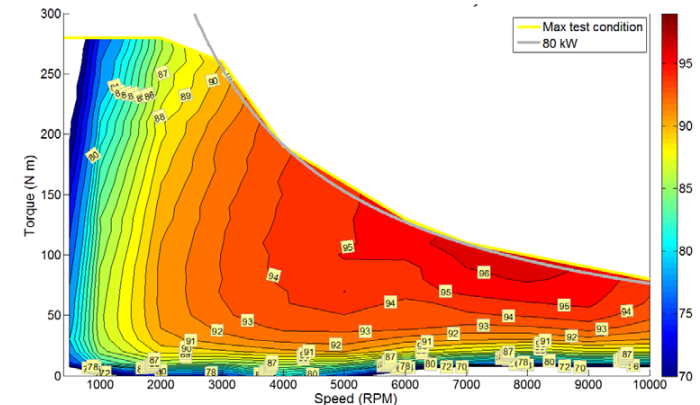
- **“Validate, in a systems context, performance targets for deliverables from the Power Electronics and Energy Storage Technology R&D activities” ***

***Reference: Vehicle Technologies Multi-Year Program Plan 2011-2015:**

http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/vt_mypp_2011-2015.pdf

OBJECTIVES

- **Enhance current benchmarking and prototype evaluation capabilities:**
 - Steady state characterization
 - Transient based testing
 - Hardware in the loop testing with a vehicle perspective
- **Evaluate current and proposed electric machine and power electronics technology in the context of a vehicle:**
 - Quantify benefits of component technology at powertrain and vehicle levels
 - Determine areas/regions for component design improvement based upon vehicle and usage considerations



FY2014 MILESTONES

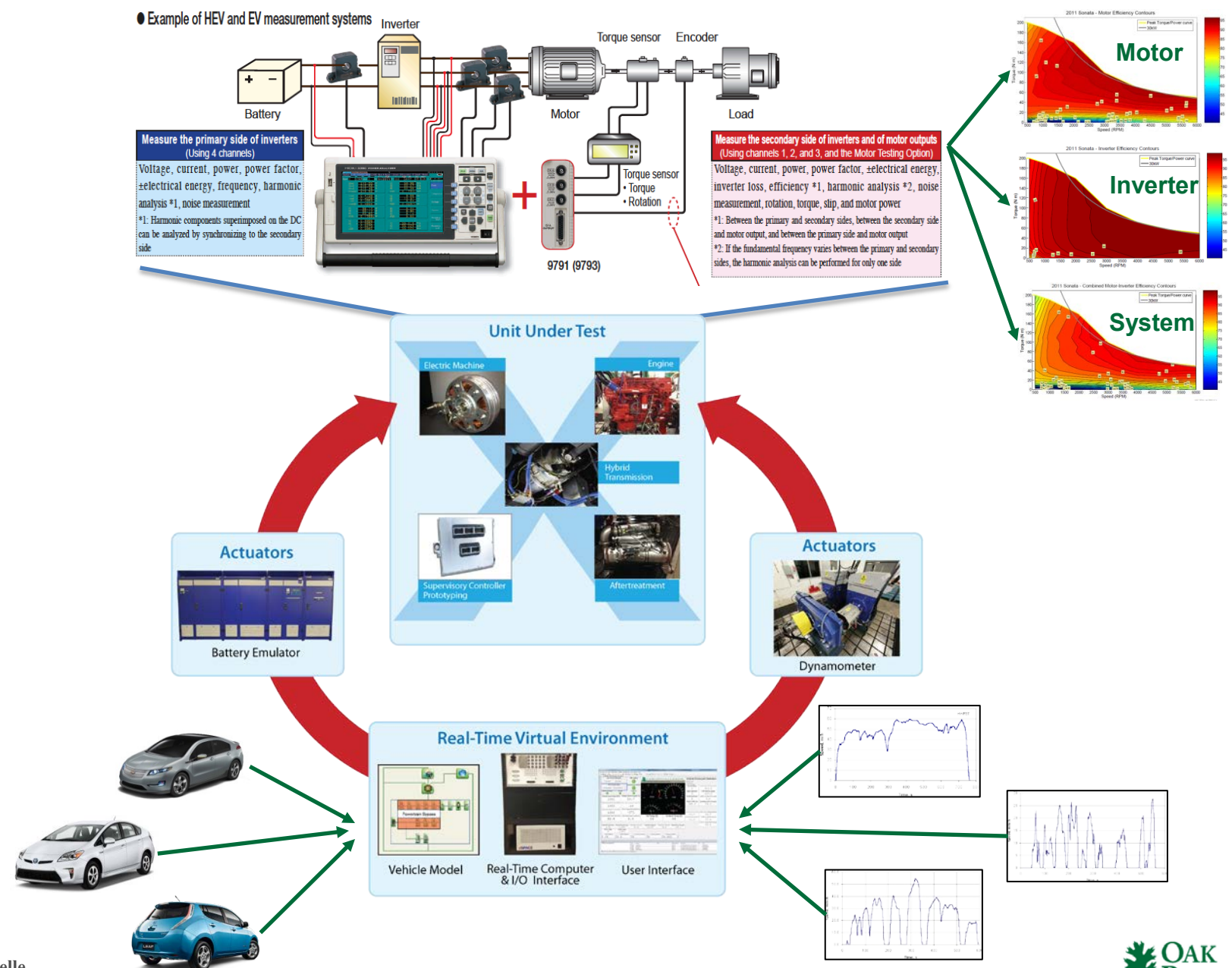
Month /Year	Milestone or Go/No-Go Decision	Description	Status
Dec 2013	Milestone	Procurement of dynamometer and testcell controller	COMPLETE
March 2014	Milestone	E-storage unit commissioning	COMPLETE
June 2014	Milestone	Test cell commissioning	ON SCHEDULE

APPROACH(1): ORNL VSI Component Test Cell – Enhanced APEEM Benchmarking & Evaluation

- **VSI Component Test Cell allows enhanced evaluation of APEEM technologies with transient operation and emulated vehicle characteristics**
 - Allows more detailed data collection through ease of complete instrumentation
 - Hardware-in-the-loop provides capture of not only steady state operating points, but transient behavior associated with real-world operation
 - Flexible real-time system allows
 - Any drive cycle, standard or custom, to be exercised
 - Single system (motor plus inverter) can be exposed to matrix of various powertrain architectures/operating envelopes
- **AVS modeling and simulation experience leveraged to support analysis of APEEM component design and development**
- **Transient, HIL based testing should be part of standard evaluation protocol for ALL technologies!**



APPROACH(2): ORNL VSI Component Test Cell – Enhanced APEEM Benchmarking & Evaluation



BACKGROUND: ORNL VSI Laboratory comprised of two distinct test cells

The VSI Laboratory houses unique test cell capabilities for full powertrain and component-level evaluation and development. Both test cells include access to:

- An AVL 400 kW energy storage system emulation with flexibility to simulate different energy storage systems as part of “X”-in-the-loop evaluations or when batteries are still in development
- A dSPACE hardware-in-the-loop (HIL) real-time platform for vehicle system emulation

VSI Powertrain Test Cell

- Uniquely capable of analyzing light-duty to full heavy-duty Class 8 powertrains
- Configurations available to evaluate and characterize engines, electric machines, transmissions, and integrated powertrains



VSI Component Test Cell

- Component “X”-in-the-loop environment including engines, electric machines, and energy storage systems
- Light-duty focused with medium-duty powertrain component capability

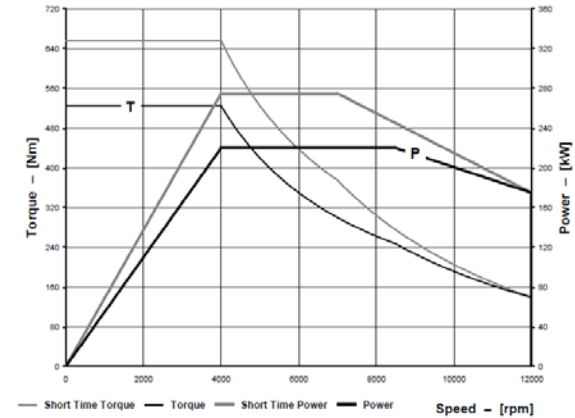
Test cell specifications:

- An AVL 250 kW, low-inertia dynamometer capable of absorbing 525 N·m of continuous torque and providing 470 N·m of motoring torque
- 12,000 rpm high-speed capability
- Double-ended option to have two independent experimental set-ups simultaneously
- Developed through collaboration of DOE VSST & APEEM

ACCOMPLISHMENT (1): Procurement and Commissioning

- **Double ended dynamometer**

- 220kW, 525Nm
- High speed: 12000rpm
- Low Inertia: 0.32kg.m²
- Order placed Q2 FY13
- Received December 2014



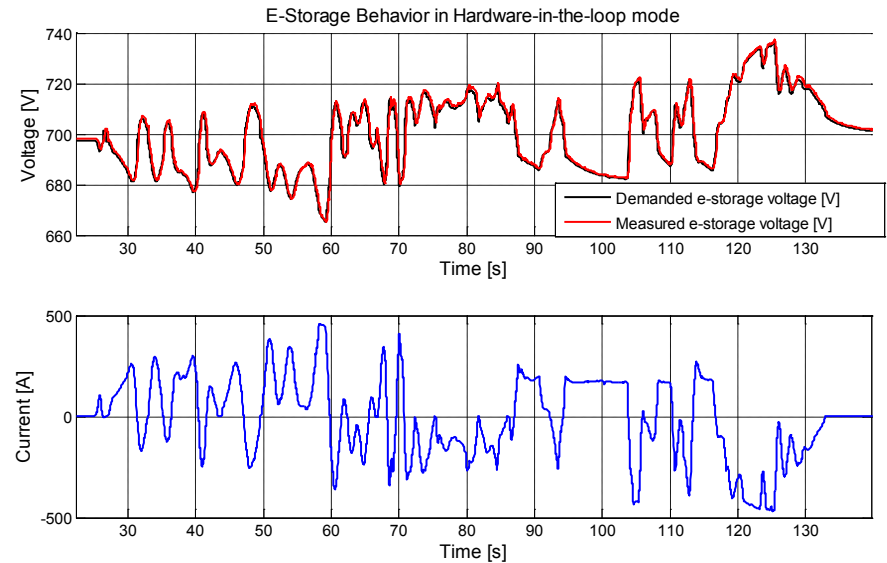
- **Test cell commissioning**

- Bed Plate procured and in place
- Dynamometer and controller in place
- Electrical installation scheduled for May 2014
- Dynamometer commissioning scheduled for June 2014



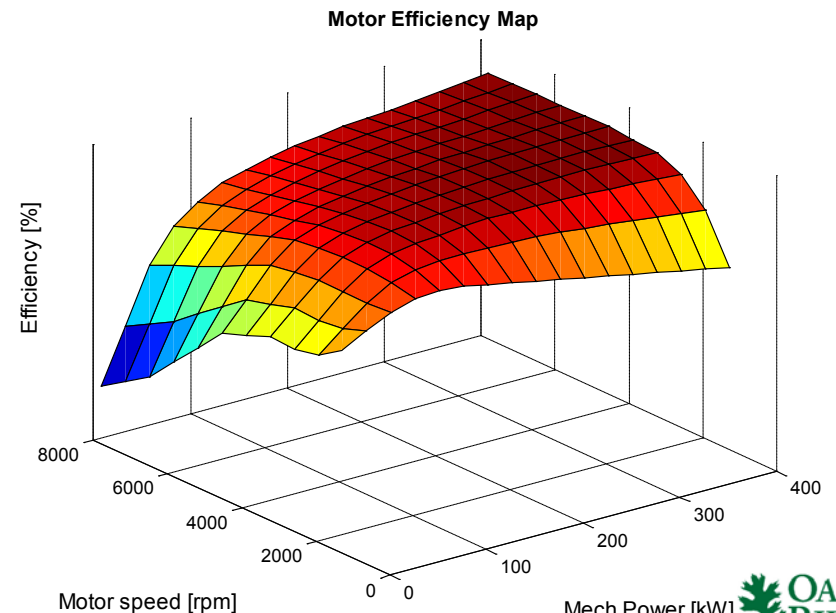
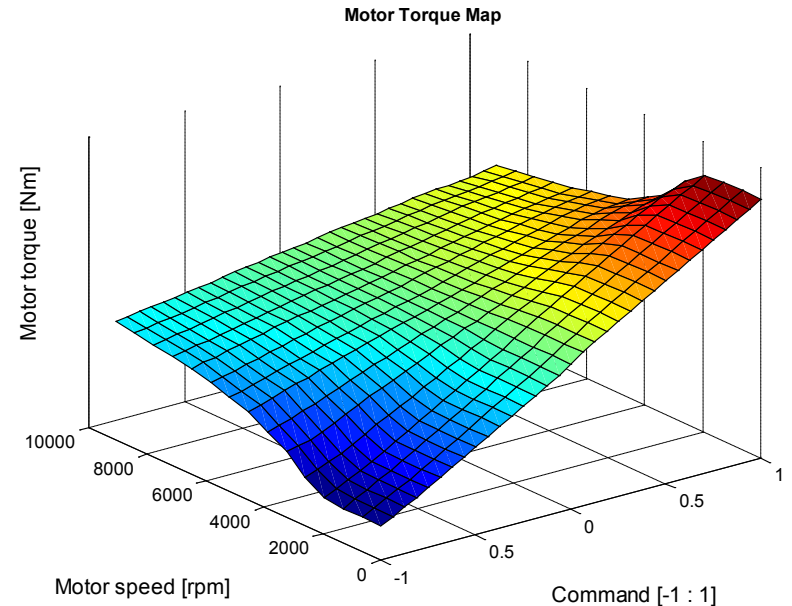
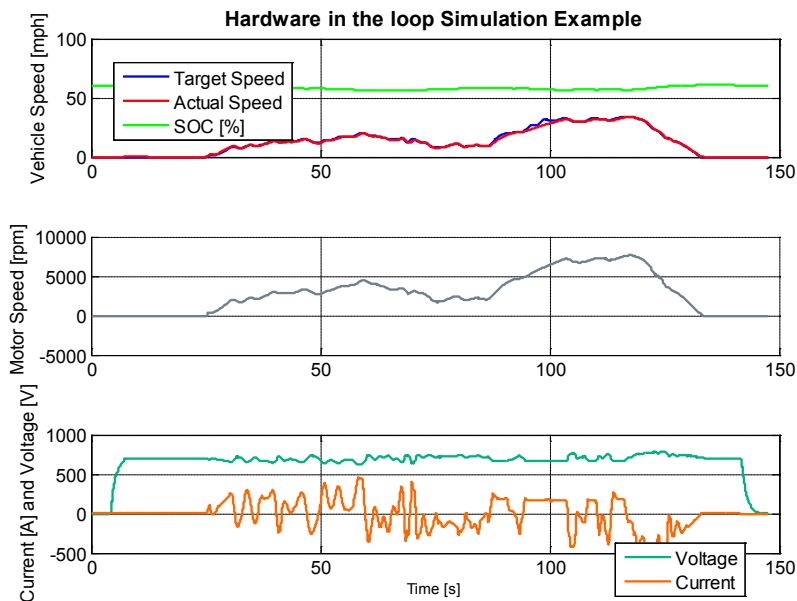
ACCOMPLISHMENT (2): E-Storage Commissioning

- **E-storage unit a.k.a. battery emulator**
 - 400kW
 - 800V
 - 600°
- **Procured part of VSI powertrain testcell**
- **Shared with component test cell**
- **Commissioned in January 2014**
- **Demonstrated on hybrid powertrain installed in powertrain testcell**



ACCOMPLISHMENT (3): E-machine Characterization

- E-storage unit was used in coordination with ORNL VSI Powertrain Test Cell to characterize electric machine
- Hardware in the loop set-up allows to test electric machine part of hybrid powertrain as if it were in a vehicle



COLLABORATION AND COORDINATION

- **Oak Ridge National Laboratory Power Electronics & Electric Machinery Group**

- Collaboration on APEEM electric machine benchmarking activities

- **VTO Advanced Power Electronics & Electric Motors**

- Funding for procurement and commissioning activities



- **USDRIVE EE Tech Team - VSATT**

- ANL gathers information on system operation at the vehicle level using APRF facility
 - **Coordinates** with APEEM/ORNL to determine if VSATT vehicle testing queue matches EETT component benchmarking needs
 - **Characterizes** inverter operation (DC in, AC out, efficiency), provides data to ORNL
- ORNL runs benchmark tests
 - Creates standard **steady state efficiency maps** for inverter, motor, and system
 - Provides **transient efficiency results** for inverter, motor, and system based upon
 - Matrix of relevant powertrain architectures
 - Standard and/or custom drive cycles

PROPOSED FUTURE WORK

- **FY2014:**

- Complete test cell commissioning
- Characterize electric machine out of Cummins MD & HD Accessory Hybridization CRADA to validate test set up

- **FY2015 :**

- Nucleate boiling project in collaboration with ANL:
 - Adapt nucleate boiling technology to motor and inverter cooling system
 - Demonstrate cooling system in realistic real world conditions using hardware in the loop platform
- General support for DOE APEEM program
 - Vehicle level modeling to understand impacts of APEEM technologies at the system level
 - Enhanced benchmarking for OEM and prototype PEEM technologies

SUMMARY:

- **Relevance**

- Validate, in a systems context, performance targets for deliverables from the Advanced Power Electronics and Electrical Motors R&D activities

- **Approach**

- Procure and commission a test cell suitable to characterize steady state and transient behavior of hybrid electric powertrain components.

- **Technical accomplishments and Progress**

- Completed procurement activities.
- Commissioning activities under way
- Performed preliminary electric machine characterization.

- **Collaborations:**

- ORNL Power Electronic and Electric Machinery group and DOE APEEM
- USDRIVE EE Tech Team

- **Proposed Future Work**

- Support DOE APEEM programs with new test facilities.
- Joint project with ANL to understand application of nucleate boiling to power electronics cooling

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